CULTURE OF CRAMBE . . .

A NEW INDUSTRIAL OILSEED CROP

Production Research Report No. 95

Agricultural Research Service
U.S. DEPARTMENT OF AGRICULTURE

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SUMMARY

Crambe, a source of glyceride oil rich in erucic acid, is a potentially important new industrial oilseed crop. Erucic acid and its derivatives can be used in a variety of industrial products. The residual seed meal, while high in protein content, contains sulfur compounds which presently limit its use for feed.

Widely distributed test plantings show that crambe is adaptable to some of the wheat-growing areas of the Pacific Northwest and upper Midwest as a spring crop and possibly in Texas as a winter crop. Adequate adaptability studies have not been conducted in the Northeast.

Cultural and fertilization practices for crambe are similar to those used for small grains. The crop is planted in narrow rows with a grain drill and harvested, either as a direct cut or after swathing, with a combine. Hulls are usually not removed from the seed by the harvesting operation. The best yields are obtained on medium-light to heavy soils that are well drained and fertile. Crambe responds to irrigation but also yields well under dryland conditions.

No specific recommendations have been made for use of herbicides or insecticides. Emerging seedlings usually compete effectively with weeds but fields known to be heavily infested should be avoided. Stand-establishment difficulties, weed competition, and seed shattering are the most important production problems. Crambe shows a high degree of immunity to insect damage; and diseases have not been very serious although some have been observed.

Because of a limited plant breeding program, no varieties have been developed.

Crambe's economic potential as compared to flax and small grain crops appears favorable but will vary with the cropping area. Cropping feasibility studies for areas where crambe has not been tested are suggested before large-scale production is initiated.

The introduction of crambe into American agriculture will provide farmers with an alternate crop to grow on farmland that would otherwise produce crops less in demand. In addition, a more stable domestic source of vegetable oil high in erucic acid will be available to industry.

Prospective growers should be sure that the crop is adapted to their area and agricultural operations. They should have a prearranged outlet for the seed, preferably on a contractual acreage basis. Following these suggestions will help prevent individual disappointment and loss of income and help assure the orderly development of crambe as a new crop.

INTRODUCTION

Crambe abyssinica is emerging from the new crops development program as a promising oilseed source of glyceride oil rich in erucic acid. With the establishment of crambe as a commercial crop, a raw material not presently produced by U.S. farmers will be available to industrial users. Crambe oil will not compete directly with domestic seed oils in industrial applications because the erucic acid oil now used comes largely from imported rapeseed oil. The market outlets for erucic acid, while presently limited, are expected to expand as the crop becomes firmly established and as further end-product uses are developed.

The chemical composition of crambe seed is similar to that of rapeseed and other mustards,

but the erucic acid content, which constitutes about 54 to 60 percent of the oil, is higher. The seed is rich in protein and oil. The seed meal contains sulfur compounds (thioglucosides) which affect the nutritional value and palatability. Thus, use of the meal will be restricted until methods for producing a nutritious and palatable livestock feed are found.

Approval was given for crambe production on diverted acreage under the 1965 Feed Grain program with the same 30-percent partial payment as for mustard seed production.

BOTANICAL DESCRIPTION

Crambe abyssinica Hochst. ex R.E. Fries, a member of the mustard (Cruciferae) family, is an erect annual herb with large pinnately lobed leaves (fig. 1). Plant height varies from about 24 to 36 inches or taller depending on the season and the plant density. Flowers are white, numerous, very small, and develop in panicled racemes. The spherical fruits are usually one-seeded and indehiscent (fig. 2). Despite indeterminate flowering, the fruits formed usually adhere until the later ones mature. The adherence of the pericarp (hull or pod) at harvest facilitates separation of crambe from other small seeds. Unless indicated otherwise, reference to crambe seed in this report will imply seed in hulls.

Species of *Crambe* occur in countries bordering the Mediterranean Sea, in western Europe, and in central Asia. Two species, *C. maritima* L. and *C. cordifolia* Steven. are cultivated on a limited basis. *C. hispanica* L., an annual, is very closely related to *C. abyssinica*. In fact, there is some question concerning the possible synonymy of these two names.

In the United States, the generic name *Crambe* and Abyssinian mustard are used as common names for *C. abyssinica*. Crambe may be referred to as Abyssinian kale, colewort, or katran in other countries.

HISTORICAL

Seed of *C. abyssinica* was first introduced into this country by the Connecticut Agricultural Experiment Station in the 1940's. As a result of encouraging preliminary utilization studies of the seed in 1957, extensive field research was started. A 1958 Swedish introduction, P.I. 247310 (Plant Introduction number), was the main source of seed for experimental plantings until 1962. Most of the field results have been obtained from seed increases of this particular introduction.

Research on crambe started much earlier in other countries. Agronomic testing in Russia began in 1932 and has continued. Over the years, evaluations have extended to Sweden, Denmark, Lithuania, Poland, Germany, Canada, and Venezuela. In most of these trials, crambe showed excellent agronomic possibilities. Although some interest was expressed in industrial usage of the oil for soap, textile manufacture, and medicinal purposes, the prime interest was for an edible oil.

RESEARCH AND DEVELOPMENT PROGRAM

The research program on crambe is carried out cooperatively by the Agricultural Research Service and State agricultural experiment stations. The procurement of seed from other countries is coordinated by plant scientists in the Crops Research Division of ARS. This division and cooperating State agricultural experiment stations are responsible for cultural and breeding studies. Chemists in the Northern Utilization Research and Development Division of ARS analyze samples from cultural and breeding trials, carry out extraction studies, and conduct extensive research on the chemistry, processing, and uses for the seed-derived oil and residual seed cake.

Considerable data from detailed cultural studies conducted in several areas are presented in this report. However, the breeding program must be considered in its infancy. Perhaps the most noticeable variation within and between individual introductions is in the time required for the plant to mature. Characteristics on which research is conducted include shattering and lodging resistance, uniform maturity, and increased seed and oil yields. Reduction or elimination of seed thioglucosides represents another important breeding objective. Although germ plasm has been quite limited in the past, several introductions now provide a

fairly broad selection base for crambe improvement.

The oil or oil-derived substances, especially erucic acid, represent the best envisioned market outlet. Crambe oil shows potential as a raw material for continuous steel casting (*2, 39*),[1] lubricants, rubber additives (*31, 32*), plasticizers (*23, 31*), new kinds of nylon (*34*), waxes (*33*), polymers, alkyd resins, and other products. Characterization of seed oil and meal constituents have been reported by utilization workers (*5, 6, 7, 12, 17, 19, 20, 21, 28, 29, 35, 36*). Compositional differences among crambe seed samples and between seed (fruit) components are considerable and are attributed in part to cultural and climatic factors (*9*). A procedure for purification of erucic acid for laboratory use has been described (*10*). Standard equipment has been found suitable for processing crambe seed (*1*). Considerable research effort is in progress on improved processing of seed and meal (*13, 14, 22*).

CULTURAL INVESTIGATIONS

Observational and cultural plantings have been made in many areas of the United States since the initiation of the crambe research program. Objectives of such plantings are concerned with the (1) evaluation of the agronomic potential, (2) delineation of suitable production areas, (3) development of preliminary cultural practices and production information for use in potential production areas, and (4) selection of high-yielding varieties. Since crambe is widely adapted to different regions, specific cultural practices have not been worked out for local conditions, but general cultural recommendations have been published (*37*). Only single-year data, which are less reliable than 2- or 3-year data, are available in several studies. Further refinement of cultural methods will be largely the responsibility of State researchers and perhaps of those processors or oil users that contract for acreage. In the initial commercialization of crambe, acreage is likely to be located near processing plants.

Climatic, Soil, and Rotation Requirements

Crambe is a cool-season crop and is adapted as a spring crop in the wheat-growing areas of the Pacific Northwest and in the northern part of the Corn Belt. Only a few plantings have been made in the Northeastern States and some of the results are inconclusive. Excellent seed yields have been obtained in Ottawa, Canada (*18*). In southern Indiana, crambe is being considered as a drill crop where frequent row-cropping is not desirable.

As a winter crop, crambe has potential in the blacklands area of Texas. A yield of 785 pounds of seed per acre was obtained at Thrall in 1961 despite late planting and low rainfall (*38*).

Medium-light to heavy soils that are fertile

FIGURE 1.—Appearance of a crambe plant at the early fruiting stage.

[1] Italic figures in parentheses refer to Literature Cited, p. 19.

and well drained are suitable for crambe production. Good yields can be obtained on sandy soils provided nutrients and moisture are sufficient. According to Robinson (*25*), leaves of crambe, mustard, and rape wilted in hot, dry weather before small grain plants in the same field showed injury. However, McGregor and others (*18*) reported that crambe withstood drought conditions better than Rocket flax. Crambe is probably about as tolerant of drought conditions as small grain crops, or a little less so.

Replicated yield data show considerable variation for widely separated U.S. plantings (table 1). Factors causing yield variations include differences in (a) cultural practices such as planting dates and row width, (b) climatic conditions, especially quantity and distribution of moisture, (c) fertility levels, and (d) damage or losses caused by weeds, insects, diseases, wind, and hail. These small replicated tests are usually hand weeded. Location comparisons may not be valid and thus may lead to erroneous conclusions.

Rotation of crambe with other crops is recommended to avoid a buildup of insects and disease organisms. Crambe should not succeed itself or related crops such as rape and mustard. It would fit into the rotation after small grain or flax, and could also be planted on fallow land. The suitability of crambe as a companion crop for forage legumes and grasses has not been determined. Good growth of the forage crop coupled with late crambe maturity could pose harvesting problems. Typical companion crops would normally be harvested earlier than crambe. Fields with serious weed problems should be avoided.

Date of Planting

Planting dates vary by location and annual climatic variation. Generally, early planting favors high yields. Crambe can, however, be injured or killed by freezing, particularly at the seedling and early flowering stages.

For winter plantings in Texas, seeding should be accomplished as soon as the danger of tem-

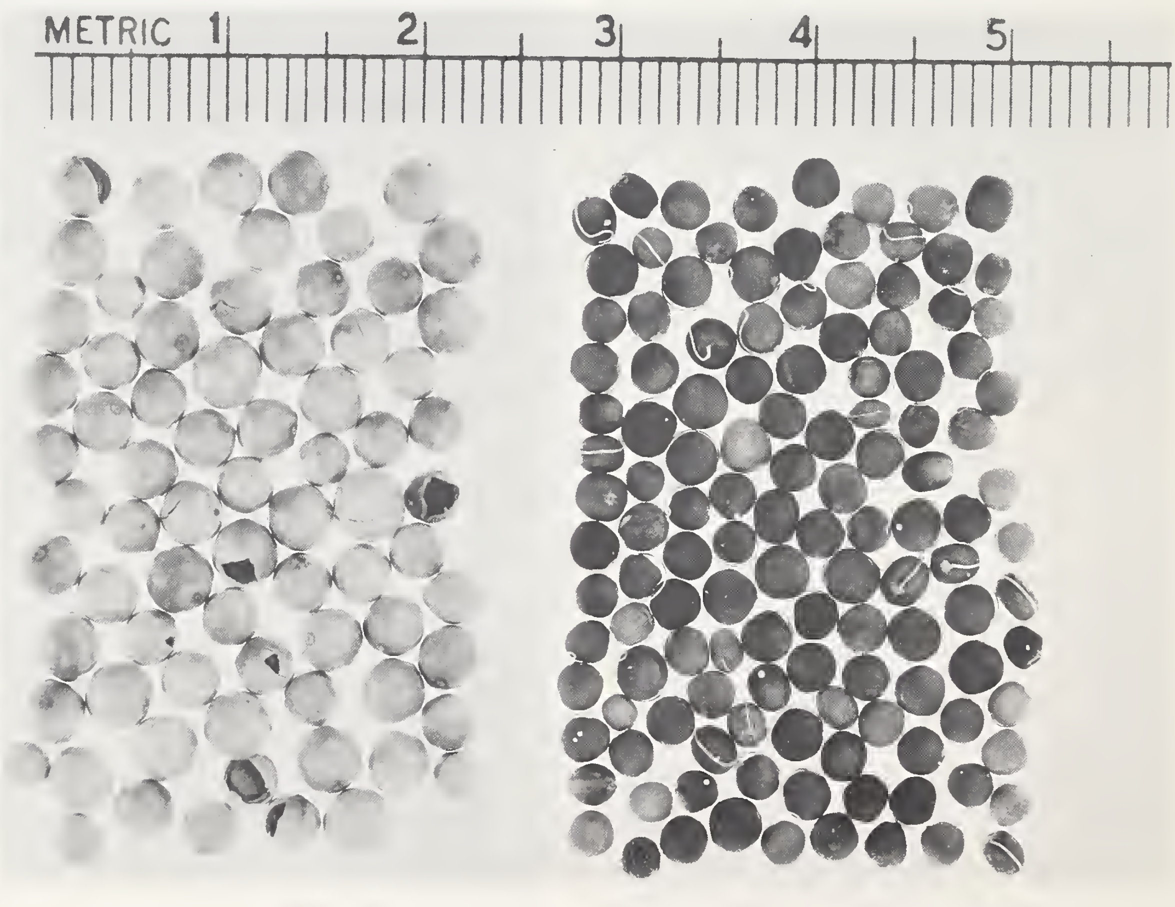

FIGURE 2.—Crambe seed (left) with hulls or pericarp intact, and (right) with hulls removed.

peratures below 24° F. has passed. Excellent yields were obtained from February experimental plantings (replicated) at College Station, Tex. (table 1), but most December and January plantings have been winterkilled. An unseasonal low of 12° F. in January 1961 at Weslaco, Tex., killed crambe plants at the seedling stage (*31*).

In spring cropping areas, plant maturity may not be attained before fall freezes if planting is overly delayed. In general, planting dates for spring-grown rapes and mustards are suitable for crambe. Recommended planting dates for crambe and these related plants in Minnesota are May 5 to 20 in the north and late April or early May in the south (*25*). Examples of planting dates for experimental plots are given in table 1.

Three May planting dates in a 1962 Wyoming irrigated experiment with three replications had no significant effect on crambe seed yields, as shown:

Planting date	*Pounds of seed per acre (36-inch rows)*
May 8	1,541
May 18	1,643
May 28	1,398

Plants of June 9, 18, and 27 planting dates did not mature. Similarly, in a 1964 Oregon trial with four replications, periodic planting dates from February 25 to May 8 did not significantly influence yields. No seed was obtained from a June 18 planting.

In contrast to the Wyoming and Oregon results, planting dates affected seed yield, oil per-

TABLE 1.—*Crambe seed yields from experimental plantings for different areas of the United States, 1958–65* [1]

Location and planting date	Row width	Seed yield per acre
	Inches	*Pounds*
Dubois, Ind.:		
May 20, 1964	14	819
Lafayette, Ind.:		
May 13, 1964	14	454
April 15, 1963	14	1,882
April 26, 1962	7	1,595
Do	14	1,389
Ames, Iowa:		
April 25, 1964	12	128
April 6, 1963	12	989
April 23, 1962	12	778
Manhattan, Kans.: [2]		
April 1, 1965	10	749
Do	20	836
April 10, 1963	10	272
April 4, 1962	18	521
May 6, 1961	18	408
April 14, 1961	18	174
May 24, 1960	18	829
April 21, 1960	18	322
Rosemount, Minn.:		
May 11, 1965 [2]	6	606
April 27, 1964	6	904
April 13, 1963	6	694
May 2, 1962	6	1,590
May 3, 1961	6	1,700
Sidney, Mont.:		
May 15, 1965	8	[3] 2,036
Carrington, N. Dak.:		
May 24, 1965	12	966
Fargo, N. Dak.: [4]		
May 12, 1965	12	2,141
May 14, 1964	12	424
May 10, 1963	12	1,913
June 20, 1962	12	(5)
May 23, 1961	12	(6)
May 17, 1960	12	587
May 15, 1959	12	1,087
May 16, 1958	12	1,148
Langdon, N. Dak.:		
May 17, 1965	12	1,235
Minot, N. Dak.:		
May 14, 1965	12	1,766
Williston, N. Dak.:		
May 15, 1965	12	894
May 20, 1965	12	[3] 1,900
Corvallis, Oreg.:		
March 24, 1964	12	[3] 2,048
March 10, 1963	12	[3] 2,284
April 12, 1962	12	[3] 2,318
Landisville, Pa.:		
April 29, 1965	14	1,336
May 12, 1964	14	793
April 17, 1963	12	[3] 377
Brookings, S. Dak.:		
May 29, 1964	20	766
May 8, 1963	18	1,259
Watertown, S. Dak.:		
May 29, 1964	20	682
June 5, 1963	18	2,070
College Station, Tex.:		
February 20, 1964	7	1,000
February 15, 1963	20	1,850
February 9, 1962	20	1,670
Fairfield, Wash.:		
May 4, 1965	12	1,175
Pomeroy, Wash.:		
April 6, 1965	12	320
Pullman, Wash.:		
April 30, 1965	12	1,785

[1] The reported yield figures are averages from replicated plots and are considered representative for the particular location under the conditions of the experiments. Increase seed of P.I. 247310 was used unless noted otherwise.
[2] Seed of N.U. 24427 was used.
[3] Irrigated.
[4] Seed from Canada was used.
[5] Planting was late because of late rains. Excessive rainfall in July damaged stands which were subsequently attacked by flea beetles.
[6] Stands were too thin for valid yield determinations. Flea beetles damaged flower buds.

centage, and bushel weight at Lincoln, Nebr., in 1962 (fig. 3). Seed yields decreased from about 1,500 pounds per acre for an early April planting to 500 pounds per acre for a May 23 planting. Plants of the April 25, May 2, and May 9 plantings were somewhat taller than plants of earlier and later plantings.

Date-of-planting tests were conducted at Bozeman, Mont., in 1962 and 1963 (table 2). In 1962, yield decreases were great as planting was delayed into June. The oil percentage and test weight of seed were much lower for the June plantings than for the May plantings. The last killing frost in the spring (31° F.) occurred June 7 and the first one of the fall (31° F.) occurred August 30. The frost-free period was 84 days as compared to a 5-year-average of 98 days. Neither of the frosts had any visible effect on crambe.

In 1963, the last killing frost in the spring occurred on May 21 and the first in the fall occurred on October 15. In this unusually long frost-free period of 145 days, differences between seed yields from the four planting dates were not statistically significant. The oil percentage in the June planting was lower than in the May plantings; the need for a long ripening period or for warm temperatures may be indicated for attainment of maximum oil production.

Results from these date-of-planting studies and other trials show that crambe should be planted in Montana as early as the ground can be prepared, or about when sugarbeets would be planted. Heavy frosts could result in stand losses, but over a period of years, a gain in oil production should offset reseeding costs. Planting should not be delayed much beyond May 1.

Seeding Methods

A firm, well-prepared seedbed is desirable. Seed can be sown with a grain drill with appropriate outlets plugged to give the desired row width. Seed placement generally should not exceed an inch in depth.

In a depth-of-planting study at Glenn Dale, Md., there were marked differences in seedling emergence as the depth was increased (table 3). This study was conducted in a cold frame with a sandy loam soil. Seeds (with and without hulls) were planted on June 25, 1965, and final seedling counts were made on July 6. These tests, although they were preliminary and did not simulate field conditions, showed that crambe seedling emergence was best at a ½-inch planting depth for seeds with or without hulls. Emergence of seedlings from seeds without

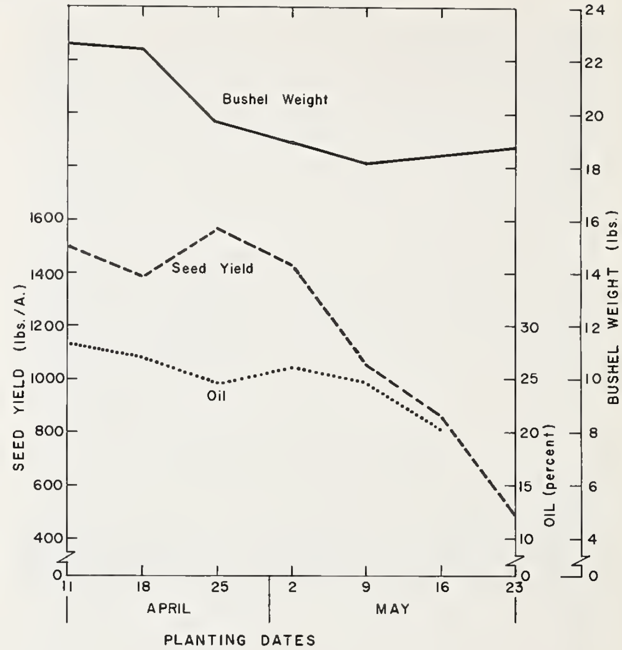

FIGURE 3.—The effect of planting dates on crambe seed yields, percent oil, and bushel weights at Lincoln, Nebr., in 1962. Oil content was determined for seeds (in hulls) with 5 percent moisture. Values are means for treatments with 0, 25, and 50 pounds of nitrogen per acre and for four replications.

TABLE 2.—*Crambe date-of-planting studies at Bozeman, Mont., 1962–63* [1]

Date planted	Seed yield per acre	Test weight per bushel	Oil content of seed
1962	*Pounds*	*Pounds*	*Percent*
May 19	1,712	24.1	30.5
May 28	1,395	25.0	29.0
June 7	452	13.0	11.7
June 17	112		4.2
Mean	918	20.7	18.9
LSD.05 (least significant difference)	444		3.2
1963			
May 15	1,902	27.1	38.1
May 22	1,803	28.6	36.5
May 29	1,767	28.3	33.1
June 12	1,752	23.8	25.7
Mean	1,806	27.0	33.2
LSD.05	(2)		3.6

[1] Plots, with 12-inch rows, were arranged in a latin square design with 4 replications, were seeded (P.I. 247310) at a rate of 10 pounds per acre, and received one 4-inch irrigation. Data from 1962 and 1963 were not combined for analysis.
[2] Not significant.

hulls was somewhat better than from unhulled seed. Petri dish tests showed a germination capacity of 95 percent or better for both lots of seed.

Under conditions of limited surface moisture and little danger of soil crusting, a planting depth of 1 to 1½ inches could be used. If seeds without hulls are used for planting, difficulty may be experienced in obtaining the proper seeding rate when using the grain box on the drill; it may be necessary to mix cracked grain or fertilizer with hull-less crambe seed in order to obtain the proper rate. The grass-seeding attachment could be used for hull-less seed, but tubes should be adjusted to drop seed in the drill furrows rather than on the soil surface.

Broadcast seeding with subsequent light disking or harrowing is not a recommended planting method. A higher planting rate would be required than for drilled seeding. Poor stands might result because of nonuniform seed placement.

TABLE 3.—*Emergence of crambe seedlings from different planting depths at Glenn Dale, Md., 1965*

Planting depth	Seeds with hulls	Hull-free seed	Mean [1]
	Percent	*Percent*	*Percent*
¼ inch	56.0	64.7	60.4 a
½ inch	63.2	70.2	66.8 a
1 inch	40.7	52.0	46.7 b
2 inches	1.2	1.7	1.5 c
4 inches	0.2	0.0	.1 c

[1] Means with letters in common are not significantly different at the 5-percent level (Duncan's Multiple Range test). Each treatment (100 seeds) was replicated 4 times.

Seeding Rates

The most commonly used seeding rate is 15 pounds of seed (in hulls) per acre for 6- to 7-inch rows. For 12- to 14-inch rows, a rate of 8 to 12 pounds should be adequate. Rates should be adjusted upward if the germination is less than 80 to 90 percent. In a 1962 Minnesota study, rates of 11, 16, and 22 pounds per acre for 6-inch rows did not result in yield differences (*25*). The seeding rate is not as important as obtaining uniform stands that will compete effectively with weeds. A good stand of crambe plants beginning to cover the rows is shown in figure 4.

FIGURE 4.—A good stand of crambe plants at Glenn Dale, Md.

Seeding rate data for a 1963 Montana trial are presented in table 4. Plots with 12-inch rows were arranged in a latin square design (5 replications) and kept weed free. Plant densities of 5.3 through 24.4 per square foot resulted in no significant differences in yields. The oil content was maximal at a stand of 14.2 plants per square foot. Assuming problems of weed competition and late maturity, a seeding rate that will result in a final stand of about 14 plants per square foot should be recommended for irrigated land or dryland (with 16 to 18 inches of precipitation) in Montana. This rate would be equivalent to about 7.5 pounds of viable seed per acre.

TABLE 4.—*Effect of seeding rate on crambe seed yield, test weight, and oil content at Bozeman, Mont., 1963* [1]

Seeding rate per acre [2]	Plant density per square foot	Seed yield per acre	Test weight per bushel	Oil content
	Plants	*Pounds*	*Pounds*	*Percent*
2.5 pounds	5.32	1,926	26.1	36.4
5.0 pounds	9.21	2,026	26.6	37.9
7.5 pounds	14.18	1,946	26.1	38.3
10.0 pounds	19.46	1,933	26.0	37.2
12.5 pounds	24.42	1,955	26.5	35.7
Mean	12.52	1,957	26.3	37.1
$LSD_{.05}$		(3)		1.47

[1] Seed, P.I. 247310, was planted May 15 in 12-inch rows. Plots received one 4-inch irrigation.
[2] Based on viable seed.
[3] Not significant at the 5-percent level.

Row Spacing, Fertilization, and Irrigation

Wyoming Experiments

In a detailed 1962 study with four replications, the best yields per acre were obtained from 18-inch rows for both irrigated (2,528 pounds) and nonirrigated (834 pounds) conditions (table 5). Although results from 18- and

TABLE 5.—*Effect of irrigation, row width, and fertilizer on crambe yields per acre at Cheyenne, Wyo., 1962* [1]

Fertilizer per acre		Distance between rows				Mean
N (pounds)	P [2] (pounds)	18 in.	24 in.	30 in.	36 in.	
IRRIGATED						
		Pounds	*Pounds*	*Pounds*	*Pounds*	*Pounds*
60	13	2,153 a B	2,282 a A	1,949 a A	1,997 a A	2,095 A
120	26	2,615 a AB	2,523 a A	2,112 b A	2,103 b A	2,338 A
240	53	2,817 a A	2,424 ab A	2,262 b A	1,811 c A	2,328 A
Mean		2,528 a	2,410 a	2,108 ab	1,970 b	2,254
NONIRRIGATED						
60	13	836 a AB	571 a A	453 a A	475 a A	584 AB
120	26	1,113 a A	982 a A	519 b A	497 b A	778 A
240	53	554 a B	552 a A	468 a A	424 a A	500 B
Mean		834 a	702 a	480 a	465 a	620

[1] Experimental plots were planted on May 8. Means within a box (heavy rules) with letters in common are not significantly different at the 5-percent level (Duncan's Multiple Range test). For interactions, uppercase letters (reading vertically) are for comparison of fertilizer rates within one spacing. Lowercase letters (reading across) are for comparison of spacings within one fertilizer level.
[2] Expressed on an elemental basis. To convert to P_2O_5, multiply the pounds of P by 2.3.

24-inch rows were similar, narrower rows might have resulted in higher yields. With few exceptions, yields decreased with increased row widths for each of the three fertility levels. At the low fertilizer level, row width had no significant effect on seed yields, for either irrigated or nonirrigated conditions. Under irrigated conditions, seed yields were greater for the intermediate and highest fertility levels than for the lowest level, but the differences were not statistically significant. The intermediate level of 120 pounds of nitrogen and 26 pounds of phosphorous was best for dryland conditions; however, seed yields were not significantly greater than for the lowest fertility level. The overall mean yield was 2,254 pounds for irrigated plots and 620 pounds for dryland plots.

Seed yields from a small 1963 irrigated experiment (four replications) were very similar for three row widths, as follows:

Row width	*Pounds of seed per acre*
6 inches	1,834
12 inches	1,809
18 inches	1,832

Excellent yields in 1961 of 2,243 and 1,976 pounds per acre were obtained from 30- and 42-inch rows, respectively (*31*).

Oregon Experiments

A randomized block design with four replications was used to study row widths in 1964 and 1965 on a Willamette clay loam. The 1964 experiment was planted on February 24, fertilized with 60 pounds of nitrogen on April 2, and irrigated on May 1. Statistically, the differences in yields for the various row spacings were not significant. The 1965 experiment was planted during the first week of April, fertilized with 48 pounds of nitrogen and 26 pounds of phosphorous at the time of seeding, and irrigated once. The yield from the 6-inch spacing was significantly greater than that from 18- and 24-inch spacings but not from the 12-inch spacing. A significant quadratic rather than a linear effect occurred because the yield from the 24-inch spacing exceeded that from the 18-inch spacing. Yields were as follows:

Row width	*Pounds of seed per acre* [1] *1964*	*1965*
6 inches	1,295 a	2,351 a
12 inches	1,262 a	1,809 ab
18 inches	1,185 a	1,551 b
24 inches	1,301 a	1,602 b

[1] Means with letters in common are not significantly different at the 5-percent level (Duncan's Multiple Range test).

In a 1963 nitrogen fertilizer test, crambe was planted on Willamette clay loam. This soil is well drained and moderately fertile. According to an analysis of variance, nitrogen levels did not produce any significant differences in yield (table 6). Seed weight (without hulls) increased somewhat as the nitrogen application increased. As expected, a progressive increase in protein content was concurrent with a decrease in oil content as nitrogen levels increased. Erucic acid content fluctuated but no consistent pattern was established. In Iowa tests, nitrogen fertilization did not influence the oil or protein content of 1963 crambe seed samples.

TABLE 6.—*The effect of nitrogen fertilization on the seed yield and on the oil, protein, and erucic acid content of hull-free crambe seed at Corvallis, Oreg., 1963* [1]

Nitrogen application per acre	Seed yield per acre [2]	Weight per 1,000 seeds	Oil content	Protein content	Protein in oil-free meal	Erucic acid in oil
	Pounds	*Grams*	*Percent*	*Percent*	*Percent*	*Percent*
None	1,410	7.1	49.1	24.8	48.7	57.5
40 pounds	1,517	7.2	46.8	26.0	48.9	56.2
80 pounds	1,240	7.4	44.6	29.6	53.4	57.6
120 pounds	1,335	7.7	44.1	30.1	53.8	57.7
80 pounds split [3]	1,402	7.5	47.3	27.2	51.6	56.9
120 pounds split [3]	1,394	7.6	44.8	29.3	53.1	58.2

[1] Seed weights and chemical data provided by the Northern Utilization Research and Development Division, ARS. The experiment was irrigated.

[2] Values are means of 4 replications. Seed yields were not significantly different.

[3] Split application of nitrogen with half preplant and half prebloom.

Fertility experiments were conducted at four Oregon locations in 1965. For these tests, a randomized block design with 4 replications, 12-inch rows, and a 15-pound seeding rate was used. Fertilizer was applied at time of seeding. Results (table 7) show that, for all locations, one or more of the fertility treatments gave significantly better yields than the check plots. The most uniform stand and highest yields were obtained from the irrigated East farm test. Lack of stand uniformity was a major problem in these experiments.

Montana Experiments

A combined study of row spacing and seeding rate was conducted at Bozeman in 1962. Plots, with three replications, were planted on May 11 and received one 4-inch irrigation. Different seeding rates were used with 6-, 12-, and 18-inch row spacings. The highest yields were obtained with 6-inch row spacings and a final plant population of about 14 plants per square foot. A seeding rate of 15 pounds per acre was used to obtain this population but the germination of the seed was low. Crambe ripens more uniformly in solid drilled plantings. Row spacing studies at Creston in 1962 (with and without irrigation) favored 7-inch over 14-inch rows but results were confounded by differences in seeding rates. Solid seeding in 6- to 12-inch rows is recommended in Montana.

Nebraska Experiments

In a 1962 study of nonirrigated crambe, with various nitrogen levels and row widths, the mean yields for 6- and 12-inch rows (1,147 and 1,003 pounds per acre), were significantly greater than mean yields for other row widths (table 8). Nitrogen rates of 75 pounds and above resulted in significantly higher yields than lower rates of application. There was no advantage in using more than 75 pounds of nitrogen per acre. In this study, seeding rates were adjusted so that approximately the same number of seeds were sown per foot of row irrespective of row width. For example, the seeding rates for 6- and 12-inch rows were 14.7 and 7.3 pounds per acre, respectively. This experiment was hand weeded.

Based on data obtained from this study, 6- or 12-inch rows and 75 pounds of nitrogen would result in highest yields.

In 1961, a seed yield of 1,616 pounds per acre was obtained from plots which received 40 pounds of nitrogen and P_2O_5 (*31*).

Discussion

Generally, row widths of 6 to 14 inches have given the best results. For dryland conditions, somewhat wider rows (18 to 24 inches) may be preferable, although weed competition might become severe unless the crop is cultivated. Seasonal conditions and fertility levels influence yield responses to different row spacings.

A fertilizer program similar to that used for small grains would be suitable for crambe production. Soil test recommendations should be followed for phosphorus and potassium fertilization. Response to nitrogen application will depend on the fertility of the soil. Fertility trials in Iowa usually have shown a response to nitrogen but results have been inconclusive in respect to the proper combination of a complete fertilizer. Under the conditions of the Iowa experiments, a nitrogen rate of 50 to 75 pounds per acre is suggested. This rate is in rather close accord with Nebraska findings (table 8).

In the Tulelake, Calif., area, crambe does very well if fertilized with nitrogen and irrigated frequently. Results of experiments on

TABLE 7.—*Effect of fertilizer treatments on crambe seed yields per acre in Oregon, 1965* [1]

Fertilizer treatment (pounds per acre) and method of application [2]	Calvert farm [3]	East farm [4]	Goetze farm [5]	Hyslop farm [6]
	Pounds	*Pounds*	*Pounds*	*Pounds*
None (check)	844 b	1,712 b	482 b	1,271 b
41 N; banded	1,220 a	1,748 b	600 ab	1,448 ab
32 N, 18 P; banded	888 b	1,883 ab	612 ab	1,703 a
62 N; broadcast	1,293 a	1,890 ab	568 ab	1,420 ab
48 N, 26 P; broadcast	1,243 a	2,058 a	664 a	1,513 ab

[1] For each location, means with letters in common are not significantly different at the 5-percent level (Duncan's Multiple Range test).

[2] Ammonium sulfate used as nitrogen source when only nitrogen was applied, a 16–20–0 fertilizer used for other treatments.

[3] Planted April 5 on a nonirrigated Chehalis sandy loam clay.

[4] Planted May 18 on an irrigated Chehalis sandy loam.

[5] Planted May 5 on a nonirrigated Olympic silty clay loam (friable hillside soil).

[6] Planted March 17 on a nonirrigated Woodburn clay loam.

mineral and organic soils are summarized in table 9.

Although mustard and rape can be injured by contact with fertilizer (*25*), no such injury of crambe has been reported. Nevertheless, low fertilizer rates are recommended when seed and and fertilizer are discharged from the same drill tubes.

In areas of limited or poorly distributed rainfall, addition of supplementary water increases crambe seed yields. Several of the experimental and seed increase plantings in Oregon, Montana, and Wyoming have been irrigated.

Weed Control

Weed competition undoubtedly represents one of the more serious production hazards. Weeds reported as particularly troublesome include wild oats, wild sunflowers, pigweed, lambsquarter, foxtail, cowcockle, pennycress, and fanweed. The planting of high-quality seed at the proper depth in a well-prepared seedbed will enhance the chances for obtaining good stands that effectively compete with weeds.

Preliminary herbicidal tests have shown encouraging results especially with ethyl *N*, *N*-di-

TABLE 8.—*The effect of nitrogen and row width on crambe seed yields per acre at Lincoln, Nebr., 1962* [1]

Nitrogen application per acre	Row width				Mean
	6 in.	12 in.	18 in.	24 in.	
	Pounds	*Pounds*	*Pounds*	*Pounds*	*Pounds*
None	815 ab B	858 a B	582 ab B	540 b B	699 B
25 pounds	1,175 a A	851 b B	515 c B	821 b AB	841 B
50 pounds	1,096 a AB	862 ab B	700 b B	691 b AB	837 B
75 pounds	1,286 a A	1,214 a A	1,028 ab A	784 b AB	1,078 A
100 pounds	1,205 a A	1,106 a AB	1,037 ab A	778 b AB	1,032 A
125 pounds	1,308 a A	1,131 ab AB	786 c AB	982 bc A	1,052 A
Mean	1,147 a	1,003 a	774 b	766 b	

[1] A split-plot design with nitrogen levels as whole plots and row spacings as subplots was planted April 13 and replicated 3 times. Plots were not irrigated. Means within a box (heavy rules) with letters in common are not significantly different at the 5-percent level (Duncan's Multiple Range test). For interactions, uppercase letters (reading vertically) are for comparsion of nitrogen levels within one spacing. Lowercase letters (reading across) are for comparison of spacings within one nitrogen level.

TABLE 9.—*Crambe seed yields from irrigated trials on organic and mineral soils with varying fertilizer applications at Tulelake, Calif.*

Kind of soil and year	Fertilizer per acre		Row width	Date		Seed yield per acre
	N	P		Planting	Harvesting	
Organic:	*Pounds*	*Pounds*	*Inches*			*Pounds*
1963	0	0	7	May 10	September 20	[1] 2,700
1965	80	43	7	May 14	October 9	[2] 3,058
Mineral:						
1964	80	43	6	May 6	September 5	[1] 4,000
1965	50	0	6	June 1	September 20	[1] 2,900
1965	50	0	12	June 1	September 20	[1] 1,700

[1] Mean for 4 replications.
[2] Mean for 3 tests each with 4 replications.

propylthiolcarbamate (EPTC) and *alpha, alpha, alpha*-trifluoro-2,6-dinitro-*N*, *N*-dipropyl-*p*-toluidine (trifluralin). The latter, although requiring soil incorporation, has been very effective in most tests. Results from herbicidal screening trials with crambe in Minnesota indicate the need for further testing of certain herbicides (*24*). Crambe is susceptible to 2,4-dichlorophenoxyacetic acid (2,4-D). Precautions should be taken to avoid possible drift damage when spraying nearby fields or fence lines. Herbicides should not be used for control of weeds in crambe until specific recommendations are made. Until more satisfactory control measures can be recommended, growers are advised to avoid planting in fields heavily infested with weeds.

Late sowing might be helpful in controlling wild oats but yields very likely will be reduced. Also, late-germinating weeds such as foxtail might become more competitive with the crop if planting is delayed. Certain herbicides were recommended for control of wild oats in rape in Canada (*8*).

Diseases and Insect Pests

Crambe has been remarkably free of diseases and insect pests. Control measures will have to be developed as the need arises. Although relatively little is known about the diseases and insect pests of crambe, the following observations may be of value to future investigations.

Perhaps the most severe incidence of disease occurred in a 1962 planting at Glenn Dale, Md. Stems, leaves, and fruits were blackened by the fungus *Alternaria circinans* (Berk. & Curt.) Bolle, and stunted plants yielded poorly (fig. 5). Previous cultivation of vegetable plants in the same plot area probably contributed to the severe infection.

Virus-like symptoms have been observed in plantings in Washington, Maryland, South Dakota, and Wyoming, but viruses have not yet been isolated and identified. Since crambe is an annual crop and viruses have not yet been demonstrated to be seed borne, the amount of virus infection probably depends on the presence of perennial crop or weed plants that might serve

FIGURE 5.—Crambe plants (left) and fruit (right) infected with the fungus *Alternaria circinans* at Glenn Dale, Md., in 1962.

as virus reservoirs and on the presence of efficient vectors. Thornberry and Phillippe (*27*), in greenhouse experiments, showed that turnip mosaic virus could be transmitted mechanically to crambe. In these tests, this virus incited systemic mottling and stunting of plants and limited floral development but was not seed borne.

In 1964 at Ames, Iowa, an infestation of false chinch bug, *Nysius ericae* (Schilling), sometime after a heavy hailstorm, reduced yields in experimental plots 60 to 80 percent from previous years. Generally, crambe is considered nearly immune to attack by flea beetles but damage to stands was reported in North Dakota after a period of excessive rainfall which also damaged stands. Apparently, damage from other sources increases the chance for insect damage. Aphids attacked crambe seedlings in Maryland. Infestation by lygus bugs (*Lygus* spp.) and leafhoppers have been reported but the extent of damage was not great.

The cabbage maggot, *Hylemya brassicae* (Bouché), feeds on the roots and underground stem portions of crambe plants. Damage is most serious during the first month of growth, and stands may be reduced. At harvest, there is no appreciable yield loss unless severe stand reduction occurs. This pest has been observed in Oregon and Washington plantings. Control consists of applying insecticides within a short period after eggs have been laid at the base of the plant. Eggs hatch within 2 or 3 days after being deposited by the flies. Spraying at about 2 weeks after plant emergence and within 10 days to 2 weeks later may be necessary for best control.

Information on diseases and insect pests and possible control measures for use with related mustard and rape crops has been published (*8*, *25*). Insects are serious pests on these crops.

Insecticidal spraying probably will not be required with crambe, at least during the first years following its establishment. Any applications should be limited to those materials that are registered for use on crambe by the U.S. Department of Agriculture Pesticides Regulation Division. For contracted acreage, spraying directions as specified by the contracting agent should be followed.

Harvesting

As the crambe crop matures, leaves are dropped and plants and seed pods turn to a light straw or tannish color. A greenish coloration of pods indicates immaturity, and further ripening may be required.

Swathing may be necessary especially in cooler areas because seeds are often mature before plants are dry enough for combining (fig. 6). Swathing just before full plant maturity

FIGURE 6.—Swathing a nearly mature crambe crop in the Palouse area near Pullman, Wash., 1962. (Courtesy V. E. Youngman, Wash. Agr. Expt. Sta.)

may offset seed shattering somewhat. The presence of green weeds or volunteer crop plants such as alfalfa may make swathing necessary.

Swathed windrows are subject to scattering by strong winds. This difficulty can be partially overcome by cutting several inches high, thereby permitting the cut material to settle in the stubble. In the Red River valley of Minnesota, some farmers with mustard acreage improvised barrel packers for their swathers to press the plant material into the stubble to prevent excessive blowing (*25*).

Direct combining is possible for a mature, dry crop. Settings for cylinder speed and clearance will depend on whether hulls are to be removed from the seeds and on how dry the crop is at harvest. With a clearance of about ½ inch and a speed of 1,400 r.p.m., 80 to 85 percent or more of the seed threshed free of the hull in an Indiana study. High cylinder speeds resulted in considerable yield loss in Minnesota trials. A speed of about 700 r.p.m. was satisfactory for harvesting seed to be used for planting. Growers are advised to harvest seed with hulls intact until more information is available on methods of removing hulls during combining.

The drier the seed crop, the more likely are hull breaking and seed splitting to occur. Cylinder speed should be reduced and the clearance widened under these conditions. Shattering may be reduced by slowing the reel speed and perhaps by removing half of the bats.

Seed Increase Plantings

Since 1962, several plantings ranging from about 1 to 50 acres have been made each year for seed increase. Yields, certain cultural information, and chemical characteristics of seed from selected locations are presented in table 10. For the most part, seed obtained from these plantings was of good chemical quality.

It should be pointed out that plantings have varied from complete failures to highly successful. The 1964 season was particularly dry, and crambe plantings were adversely affected. For example, plantings in western Nebraska and Wyoming were not successful. Poor stands and weed competition were most often mentioned as production problems. Poor seedbed preparation, deep planting, and possibly poor seed contributed to these problems.

Cultural practices used in these large plantings were generally in accord with those previously described. The listed dates of harvest are for combining either as a direct cut or from swathed windrows. The number of days needed for crambe to mature can be determined by figuring the days from planting to harvesting. For example, the periods for 1963 from North Dakota, Oregon, and Egbert, Wyo., were 112, 111, and 122 days, respectively. For Texas plantings (shown in table 1), the number of days was 90, 79, and 85 for 1962, 1963, and 1964, respectively. In Canada, three crambe strains matured in 93 to 109 days during the period 1957 to 1959 (*18*).

Germination and Seed Storage

No official germination standards for laboratory testing of crambe seed have been developed, but results from preliminary tests indicate that crambe is not very demanding as to conditions for high germination.

According to results from one germination study, testing crambe seed in the hull at 20°, 25°, or 25° to 30° C. in folded blotters moistened with water or a 0.2-percent KNO_3 solution was suggested as being satisfactory until a standard procedure is adopted (*3*). In a different study, a 20° C. dark treatment in rolled towels was shown to be the best method for germinating crambe seed (*16*). Hull-less seed germinated in 4 days and seed with hulls in 7 days (*15*). Final germination evaluation at 7 to 10 days should be about optimum (*3, 16*).

The proportion of hulls may serve as a preliminary guide to crambe quality (*31*). For example, under unfavorable growing or harvesting conditions, a high proportion of hulls would indicate unfilled pods and poorly developed seeds. The proportion of hulls to seed is usually about 25 percent or less but varies from about 10 to 45 percent. Exploratory germination tests showed that highly shriveled seed (hull-free) either produced abnormal seedlings or did not germinate (*26*).

Germination tests should be run on representative seed samples from planting stocks to allow adjustment, if necessary, in seeding rates.

Seed storage studies with controlled temperature and humidity are being conducted, but conditions in these studies do not closely simulate bin storage. Because of the wide variation in temperature and humidity in areas where crambe is adapted, bin storage of seed with and without hulls needs to be considered for both germination and chemical quality.

Tight bins will be required for storage.

Varietal Development and Breeding Program

Crambe varieties have not evolved from the breeding program. Most likely, the initial commercial acreage will involve seed originally from P.I. 247310 obtained from Sweden. Seed of this introduction should either be referred to as Crambe No. 1 or as P.I. 247310.

In 1962, seed of 10 crambe accessions from different areas in Russia was received. These

TABLE 10.—*Yields, cultural information, and physical and chemical characteristics of crambe seed from large-scale increase plantings, 1962–65*

Crop year and location	Date		Row width	Seed yield per acre	Bushel weight	Weight per 1,000 seeds [1]	Pericarp (hulls)	Protein content of—		Oil content of—		Erucic acid content
	Planting	Harvesting						Seeds with hulls	Hull-free seed	Seeds with hulls	Hull-free seed	
1962			*Inches*	*Pounds*	*Pounds*	*Grams*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
Bozeman, Mont.	May 11	Sept. 19	Varied	[2] 1,106	----------	----------	31	21.8	29.4	31.9	45.2	----------
1963												
Bozeman, Mont.	----------	----------	----------	880	24.4	5.9	32	19.3	26.6	32.2	48.3	54
Langdon, N. Dak.	May 16	Sept. 5	30	652	29.1	6.0	16	25.8	30.6	34.1	43.3	56
Albany, Oreg.	May 17	Sept. 25	12	[2] 2,102	26.2	5.9	25	22.7	25.4	39.5	49.0	58
Pullman, Wash.	May 18	Sept. 6	7	796	28.8	4.0	21	17.0	23.2	34.4	49.4	55
Albin, Wyo.	May 2	Aug. 15	10	500	26.8	5.5	24	28.5	35.2	29.6	39.3	51
Egbert, Wyo.	May 1	Aug. 31	10	[2] 2,328	27.6	5.8	22	22.9	26.9	37.9	47.4	57
1964												
Albany, Oreg.	April 1	Aug.	12	[2] 2,167	----------	----------	----------	----------	24.2	----------	49.4	58
Pullman, Wash.	April 30	Sept. 3	7	494	----------	----------	----------	----------	24.4	----------	50.6	60
1965												
Albany, Oreg.	April 1	July 25–Aug. 10	12	[2] 2,150	----------	----------	----------	----------	----------	----------	----------	----------
Pullman, Wash.	May 7	Sept. 6	7	995	----------	----------	----------	----------	----------	----------	----------	----------

[1] Hull-free.

[2] Plantings were irrigated.

Russian lines have been evaluated at several locations, and some selections have been made from them. Although the lines are similar, some variability in maturity, hardiness, and yield potential is apparent. Iowa, Minnesota, and South Dakota data on yields from the Russian lines are presented in table 11.

TABLE 11.—*Crambe seed yields per acre of 10 Russian accessions in Iowa, Minnesota, and South Dakota* [1]

Plant Introduction number	Iowa [2]	Minnesota [3]	South Dakota [4]	
			Brookings	Watertown
	Pounds	*Pounds*	*Pounds*	*Pounds*
247310 (Sweden)	845 ab	694	766 ab	651 a
281728	822 ab	573	660 b	685 a
281729	774 ab	916	724 ab	651 a
281730	861 ab	756	763 ab	701 a
281731	870 ab	801	682 b	714 a
281732	633 b	787	714 ab	709 a
281733	803 ab	1,001	726 ab	737 a
281734	578 b	758	810 a	672 a
281735	832 ab	823	683 b	692 a
281736	1,008 a	913	669 b	688 a
281737	714 ab	660	826 a	686 a

[1] For a given location, means with letters in common are not significantly different at the 5-percent level (Duncan's Multiple Range test).
[2] Planted in 12-inch rows (2 replications) on April 6 and harvested July 17, 1963.
[3] Planted in 6-inch rows (2 replications except P.I. 281729) on April 13 and harvested August 2, 1963. Statistical treatment not available.
[4] Planted in 20-inch rows (8 replications) on May 29 and harvested September 1, 1964.

Several new lines of *C. abyssinica* have been received from Sweden. Small quantities of *C. hispanica* seed have been introduced. Seed of most introductions has to be increased before evaluations can be made. Seed introduced into Canada from other countries has also been included in North Dakota (table 1) and Oregon trials. Yields obtained in 1962 at Corvallis, Oreg., from these introductions compared favorably to average yields for the period 1957-59 at Ottawa, Ontario (table 12).

TABLE 12.—*Seed yields of crambe accessions in Oregon and Ottawa, Ontario*

Number or line [1]	Original source of seed	Seed yield per acre	
		Oregon [2]	Ottawa [3]
		Pounds	*Pounds*
C.D. 6090	Poland	2,219	2,400
C.D. 6470	U.S.S.R.	2,490	2,173
C.D. 6619	Sweden	2,388	2,411
P.I. 247310	Sweden	2,318	--------

[1] C.D. and P.I. numbers refer to Canadian and U.S. (Plant Introduction) designations, respectively.
[2] Planted April 12, 1962, in 12-inch rows at 10 pounds per acre.
[3] Average yields for the period 1957–59 as reported by McGregor and others (*18*). Seed was planted in early May in 12-inch rows.

As indicated by the previous discussion, there is a fairly broad base of crambe germ plasm available for varietal development and crop improvement. In view of variation in yield and oil content, the prospect of developing varieties with improved agronomic and commercial value through use of a systematic plant breeding program is excellent (*18*).

ECONOMIC CONSIDERATIONS

Since cultural methods and equipment requirements for crambe and small grains are similar, production costs should be about the same. However, somewhat better seedbed preparation may be necesssary for crambe. Crambe is most likely to be an alternative crop for oats, barley, flax, or wheat. Average yield and price data from South Dakota indicate that crambe would return a higher gross income than either flax or wheat but not as much as corn (*11*). In an economic assessment of crambe production and use (*30*), seed yields of 477 pounds were required to equal 1954–55 average gross returns from flaxseed, and 860 pounds to equal wheat returns. Yields from experimental plantings of crambe fall within the range of these estimated requirements.

To be economically acceptable, crambe should provide returns equal to or higher than presently grown crops. Its ability to do this will vary in different areas. In areas where production costs for some crops exceed returns, crambe yields may be sufficient to insure profits. On the other hand, returns from crambe may fall below those from other crops even though it is well suited to the area. For areas where crambe has not been tested, the need for conducting crop feasibility studies previous to any large-scale production is emphasized.

Crambe was compared to other crops in Montana on a statewide basis for 3 years. Because an unsatisfactory diluent was used for seeding purposes, several of the 1964 tests were abandoned. Yield comparisons are shown in table

13. In Montana, crambe would perhaps derive its acreage from that currently devoted to barley; therefore comparisons should be between these crops. The yield data in table 13 indicate that the production of crambe under conditions that result in less than 35- to 40-bushel barley yields might be hazardous. The State average dryland barley yield is about 28 bushels (1,344 pounds) per acre but some counties consistently average 35 bushels (1,680 pounds) per acre or more. These are usually counties or areas that receive 16 or more inches of rainfall. Timeliness of rainfall is also important. Crambe shows an intolerance to high temperatures during the flowering period.

An economic comparison based on the crambe and barley yields in table 13 is given in table 14. These data should be used with caution because the following assumptions need to be confirmed or considered:

1. The area of adaptation corresponds with that of malting barley which usually commands a higher price than feed barley. Prices for all barleys are used in comparisons.

2. The cost of producing crambe and barley is assumed to be the same. This appears logical unless windrowing is necessary and the grower does not have the equipment.

3. Trials were kept weed free. Thus, it is assumed that crambe controls weeds as well as barley so that any yield reductions would be proportionate. This assumption is probably valid.

As a result of the crambe-barley comparisons, a reasonable price for crambe seed in Montana that might result in appreciable acreage would be about 4.5 to 5 cents a pound. These figures take the additional hazards of a new crop into consideration whereas the breakeven point with barley would be about 3.8 cents per pound. In terms of oil production, about 10.7 cents per pound for seed oil would be required to equal

TABLE 13.—*Seed yields of crambe compared to certain crops grown at various locations in Montana, 1962–64* [1]

Year, irrigation, and location	Planting date	Seed yields per acre				$LSD_{.05}$
		Crambe	Unitan barley	Redwood flax	N–10 safflower	
1962						
Irrigated:		*Pounds*	*Pounds*	*Pounds*	*Pounds*	
Creston	May 3	1,492	3,928	1,500	[2] 510	827
Huntley	May 4	1,890	4,388	1,042	1,647	644
Sidney	May 9	2,519	4,064	1,870	1,645	360
Bozeman	May 11	2,102	4,138	1,863	[3] 470	621
Not irrigated:						
Creston	May 3	1,305	3,742	968	1,505	1,303
Huntley	May 4	(4)	1,791	758	702	351
Sidney	May 9	1,886	3,709	1,439	1,369	459
Moccasin	May 24	(4)	1,929	387	(2)	302
Havre		[4] 133	1,566	315	540	216
1963						
Irrigated:						
Creston	May 6	758	(5)	1,628	[2] 1,591	(6)
Sidney	May 6	2,323	4,731	1,513	2,923	338
Corvallis	May 16	1,642	6,144	2,728	[2] 836	783
Bozeman	May 22	1,482	3,228	[7] 93	1,345	574
Huntley	May 27	2,935	2,697	1,260	[2] 279	385
Not irrigated:						
Havre	April 30	[4] 206	128	178	591	255
Sidney	May 6	1,554	3,251	580	1,817	340
Creston	May 7	825	(5)	1,559	2,553	697
Moccasin	May 16	[4] 244	1,412	192	(3)	152
Huntley	May 27	999	2,059	636	1,942	292
1964						
Irrigated:						
Corvallis	May 20	750	3,111	1,691	(2)	577
Bozeman	June 1	1,539	2,115	634	[3] 686	392
Huntley		[8] 490	2,845	880	1,469	

[1] 4 row plots were replicated 4 times and kept weed free.
[2] Root rot limited yields.
[3] Season too short.
[4] Drought conditions.
[5] Hail damage.
[6] Not significant.
[7] Mouse damage.
[8] High temperatures limited flowering and yields.

returns for barley. As an inducement for production of the crop, probably 12.5 to 14 cents for seed oil would have to be offered. Greater familiarity with the crop and its adaptation and culture could result in a lowering of the price that would be necessary to establish sustained production.

Inclusion of crambe in the 1965 Feed Grain Program as a mustard offered some additional incentive for growing crambe. But diverted acreage might be poorer than nondiverted acreage, and use of poor land, especially poorly drained or heavily weed infested, could lead to poor results or complete failures.

There is no firm basis for determining the price that can be paid to the grower for crambe seed (in hulls) but prices may be in the neighborhood of 4 to 5 cents per pound. The price must be based primarily on the oil, because optimum processing procedures for use of the seed meal in feed or industry are not yet known, though active research is in progress in this field. The byproduct meal because of its high nitrogen content could probably command some return as a fertilizer material. However, the value would be considerably enhanced if procedures are perfected for utilization of the meal for feed, as a desired product for plywood glues, or other applications.

An early preliminary estimate of markets for brassylic and pelargonic acids which are obtained by ozonalysis of erucic acid has been made (*4*).

TABLE 14.—*An economic comparison of crambe and barley based on results of Montana intrastate trials* [1]

Year, irrigation, and location	Crambe oil		Gross income per acre from barley	Price required to equal barley returns	
	Seed content	Yield per acre		Seed (per pound)	Oil (per pound)
1962					
Irrigated:	*Percent*	*Pounds*	*Dollars*	*Cents*	*Cents*
Creston	40.8	609	60.57	4.06	9.9
Huntley	32.6	617	67.66	3.58	11.0
Sidney	32.9	829	62.67	2.49	7.6
Bozeman	32.0	673	63.81	3.04	9.5
Not irrigated:					
Creston	42.1	549	57.70	4.42	10.5
Huntley	----	----	27.62	----	----
Sidney	29.1	549	58.19	3.03	10.4
Moccasin	----	----	29.75	----	----
Havre	12.2	16	24.15	18.15	150.9
1963					
Irrigated:					
Creston	22.3	169	----	----	----
Sidney	33.9	787	69.97	3.01	8.9
Corvallis	27.1	445	90.87	5.53	20.4
Bozeman	30.6	453	47.74	3.22	10.5
Huntley	33.2	974	39.89	1.35	4.1
Not irrigated:					
Havre	28.6	59	1.89	.92	3.2
Sidney	27.7	430	48.08	3.09	11.2
Creston	25.3	209	----	----	----
Moccasin	26.0	63	20.88	8.56	33.1
Huntley	24.9	249	30.45	3.05	12.2
1964					
Irrigated:					
Corvallis	36.7	275	49.90	6.65	18.1
Bozeman	38.3	589	33.92	2.20	5.8
Huntley	----	----	45.63	----	----

[1] Barley prices (per cwt.) used were: 1962—$1.542; 1963—$1.479; and 1964—$1.604. Refer to table 13 for seed yield data.

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